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Bloch-Front Turbulence in a Periodically Forced Belousov-Zhabotinsky Reaction

Aric Hagberg, hagberg@lanl.gov

Spatio-temporal disorder in extended systems commonly involves the spontaneous creation and annihilation of localized structures such as defects and vortices. The driving forces for the nucleation of defects and vortices are instabilities of periodic patterns or fronts. Defects in periodic patterns often result from the Benjamin-Feir-Newell instability, while spiral-vortex nucleation in bistable systems has been related to a front instability – the Non-equilibrium Ising-Bloch bifurcation.

We have demonstrated, in a periodically forced oscillatory Belousov-Zhabotinsky reaction and in mathematical models, a mechanism for creating spatio-temporal disorder. The mechanism consists of the creation of spiral vortex pairs through a transverse instability of fronts in the vicinity of a nonequilibrium Ising-Bloch bifurcation. This is the first direct experimental evidence tying front instabilities to vortex nucleation and disorder.

We used an amplitude equation model, the forced complex Ginzburg-Landau equation, to reproduce the experimental observations with numerical solutions, and further described the mechanism for vortex creation with the normal form equations for a curved front line.

Co-investigators

Bradley Marts, Anna L. Lin, Department of Physics, Duke University, Durham, NC 22708-0305 Ehud Meron, J. Blaustein Institute for Desert Research, Ben-Gurion University, Sede Boker Campus 84990

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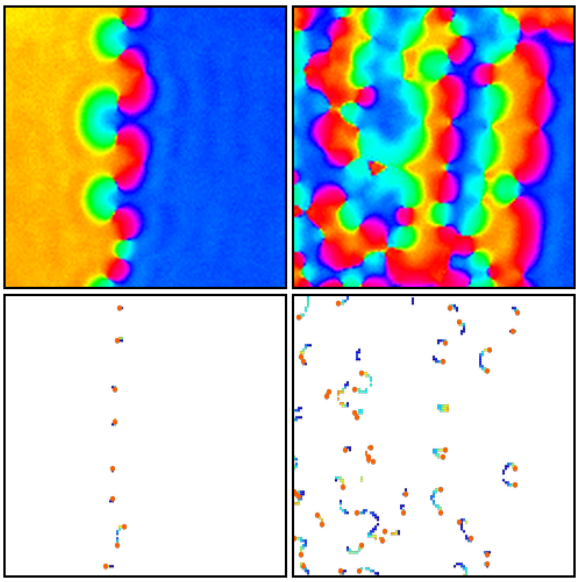

Experiments on a periodically forced Belousov-Zhabotinsky chemical reaction show front breakup into a state of spatio-temporal disorder involving continual events of spiral-vortex nucleation and destruction. The initial front of the oscillation phase is unstable to transverse perturbations and vortices form in pairs along the front line. The bottom frames show the position of the vortices, the core location of the spiral wave, as red dots with colored tails indicating the motion and direction of travel. Our amplitude equation models capture the spatio-temporal dynamics of the chemical system and equations for the curved front line reveal the mechanism for spiral-vortex nucleation.

References

[1] B. Marts, A. Hagberg, E. Meron, and A. L. Lin. Bloch-front turbulence in a periodically forced Belousov-Zhabotinsky reaction. *Phys. Rev. Lett.*, 93:108305, 2004.

For further information, movies, and research papers see http://math.lanl.gov/BlochFront/